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Detecting inflation regime shifts in the euro area: the role of money growth

This study employs an adjusted money growth indicator to identify inflation regime shifts in the euro area. A two-regime LSTAR model reveals that when adjusted M3 growth surpasses 5%, a high-inflation regime typically follows after about ten months. This regime is marked by persistent dynamics and a higher average inflation rate. The inflation surge from early 2021 to late 2022 aligns with periods of elevated adjusted money growth, underscoring the value of such indicators as complementary tools for tracking and anticipating inflation regime changes.

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Money signals regime shifts

Adjusted M3 growth above 5% triggers a transition to a high-inflation regime with an approximate ten-month lead. This 5% threshold was empirically estimated and provides policymakers with an early warning of potential inflation upturns.

High inflation shows persistence

Once in the high-inflation regime, inflation exhibits strong autoregressive dynamics, suggesting that elevated inflation persists longer.

Model captures post-pandemic spike

The smooth transition model successfully identifies the 2021–2022 inflation surge, with regime probability peaking in January 2022 ahead of the 11.6% inflation peak in October 2022, validating the framework's real-world applicability.

Abstract[1]

This study investigates the usefulness of an adjusted money growth indicator for detecting inflation regime shifts in the euro area over the period 1997–2024. We apply a two-regime Logistic Smooth Transition Autoregressive (LSTAR) model in which transitions between low- and high-inflation regimes are determined by a smoothed measure of broad monetary aggregate M3 growth, adjusted for trends in velocity and output. Our analysis indicates that the high-inflation episode in the euro area from early 2021 to late 2022 coincides with periods in which adjusted M3 growth exceeds 5%, with an estimated lead of approximately ten months. Conditional on this indicator, we find that the high-inflation regime is characterised by persistent dynamics and elevated mean inflation. Overall, our results suggest that appropriately adjusted money growth indicators may provide useful complementary information for identifying potential turning points in inflation and improving monitoring of regime changes in the euro area.

> “I’m tired of the eternal ‘if and when’:
> We’re short of gold, well fine, so fetch some then.”
> (The Emperor to Mephistopheles in *Faust II* (1832),
> J. W. Goethe, Act 1, Scene 2)

1 Introduction

In Goethe’s “Faust II,” the Emperor’s frustration with financial scarcity leads to the creation of money not backed by precious metals, such as gold, but by the trust of its users. This act, turning faith into liquidity, lies at the core of fiat money. Mephistopheles’ promise after the Emperor’s wish, “I’ll fetch what you wish, and I’ll fetch more,” captures the appeal and danger of unconstrained money creation, which lies at the heart of enduring debates about fiat monetary systems: Does money creation inevitably lead to inflation? As former Bundesbank President Jens Weidmann (2012) noted in a speech invoking this very scene, this thought experiment in money creation eventually gives way to inflationary pressures that erode the value of money and undermine the monetary order. Written in 1832, Goethe’s episode dramatises a timeless tension at the core of monetary economics: the relationship between monetary growth and inflation.

Nearly two centuries later, the global post-pandemic inflation surge, which started in 2021, has also revived interest in the well-studied relationship between money growth and inflation. As a central element of the quantity theory of money (Friedman, 1963), this relationship became an important point of contention in both academic literature and policymaking. While the causal relationship was frequently contested, a link between money growth and inflation was often observed as an empirical regularity. However, support weakened in the long period of moderate inflation since the 1990s (also known as the Great Moderation period). With the recent return of high inflation in advanced economies, both monetary policymakers and economists have revisited the topic (Schnabel, 2023; Lane 2024; Amisano

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and Colavecchio, 2025). While some commentators interpret the post-pandemic developments as a vindication of the quantity theory of money (Issing, 2021), others argue that such a rare extreme event does not support a meaningful relationship (Papadia and Cadamuro, 2021).

In this paper, we scrutinise the link between money growth and euro area inflation on a monthly basis using a non-linear model featuring a low- and a high-inflation regime, where smooth switching between the regimes is triggered by adjusted money growth. We therefore follow Ringwald and Zörner (2023), who successfully employed this model for the United States, the United Kingdom and Canada. While we do not aim to identify any potential underlying causality, we apply this non-linear model to examine whether money growth has informational properties for regime shifts in inflation. In our framework, inflation is modelled as an autoregressive process, i.e. today's inflation depends on its past dynamics. Furthermore, the behaviour of inflation changes smoothly between two different regimes, depending on the value of a transition variable. We use the adjusted growth of the broad monetary aggregate M3, corrected for trends in velocity growth and output growth, as the transition variable. The transition between regimes is controlled by a logistic function, which ensures a gradual rather than sudden shift, reflecting the notion that economic agents adjust their behaviour only gradually. This flexible set-up allows us to infer both the order of the autoregressive process (that is, how far back in time the process "remembers" when determining its current state) and the delay parameter of the transition signal (that is, how many periods elapse between a money growth signal and an expected regime change) from the data. Most importantly, our set-up enables us to infer the threshold money growth indicator needed to signal a regime change as well as the speed of transition between the low- and the high-inflation regimes.

Our model successfully assigns the post-pandemic period of rising inflation, from early 2021 to the end of 2022, to the high-inflation regime. It identifies a delay parameter of approximately ten months for the money growth indicator. This reflects a comparatively short interval between the growth of the broad (adjusted) money aggregate M3 during the COVID-19 pandemic (and the preceding low-interest rate period) and the subsequent sharp increase in prices during the post-pandemic period of supply chain disruptions, the Russian invasion of Ukraine, and persistently strong aggregate demand. In contrast, the benchmark study finds a significantly longer delay of 2.5 years for the USA, but shorter delays of only zero and one quarter, respectively, for the UK and Canada, based on quarterly data. While they also abstract from any causal relationship between money growth and inflation, the results align with existing literature suggesting that a money growth measure can improve inflation forecasts in high-inflation regimes (Borio et al., 2023a) or serve as an early risk indicator of potential transitions into higher inflation regimes (Amisano and Fagan, 2013).

2 The money–inflation relationship in policymaking and academia

After years of inflation close to or even below the (symmetric) inflation target of 2% in the euro area, with policymakers employing unconventional monetary policy tools to avoid deflation, the post-pandemic period saw an inflation surge that peaked at more than 10% in 2022. While unprecedented in the relatively young euro area, this episode evoked memories of past periods of high inflation following the oil crises of the 1970s and 1980s across oil-importing countries. It also revived a debate that had lost momentum during the decades of low inflation and low interest rates leading up to the COVID-19 pandemic, namely the long-standing discussion of the relationship between money growth and inflation.

When Friedman and Schwartz (1963) published their work "A Monetary History of the United States, 1867–1960," the USA was about to enter a long period of high inflation. Despite aggregate demand pressures from Vietnam War spending, US President Lyndon B. Johnson did not follow his economic policy advisors' recommendations to increase taxes or reduce fiscal stimulus in the late 1960s, contributing to Keynesian economics' lasting stigma of being inflationary (Blinder, 2022). The demand-focused Keynesian theory at the time was also ill-equipped to respond to the supply (oil) shock-driven stagflation of the 1970s, when high inflation coincided with high unemployment. In this context, Friedman and other monetarists gained traction in both academic and policy debates. Inflation was proclaimed a monetary phenomenon, to be counteracted by central banks adhering to rigid money supply growth rules (Blinder, 2022).

Starting in the 1970s, monetary aggregates became key to central bank policy and particularly to central bank communication. While not strictly following a rigid money supply growth rule, central banks like the Deutsche Bundesbank still employed a monetary targeting strategy aimed at controlling inflation (Amisano and Colavecchio, 2025). However, by the 1990s at the latest, monetary targeting remained little more than lip service (Blinder, 2022) or a convenient communication tool (Hartmann and Smets, 2018), with most central banks beginning to target inflation directly. This change accompanied the emergence of New Keynesian models in macroeconomics, a class of models combining Keynesian ideas on aggregate demand and business cycles (assuming imperfect markets due to price stickiness) with microeconomic foundations based on the behaviour of households and firms. These models continue to provide the workhorse framework for modern macroeconomic policymaking. New Keynesian models commonly include an interest rate setting rule for the central bank that directly targets the trade-off between inflation and unemployment (Galí, 2008), such that money supply plays only an implicit role, and monetary aggregates progressively faded from policymakers' considerations.

In the Deutsche Bundesbank, and by extension in the early years of the ECB, which aimed to follow the Bundesbank's stability-oriented monetary policy strategy, monetary aggregates remained a focus for longer than in other central banks.[2] At the core of the early ECB monetary policy strategy (1999–2003) was a two-pillar framework of monetary and (macro-)economic analysis, with the monetary pillar explicitly listed first (Hartmann and Smets, 2018). For this pillar, the ECB announced a reference value for the annual growth rate of the broad monetary aggregate M3. This, however, was not intended as a strict monetary target or mechanical rule. After the ECB's evaluation of its monetary policy strategy in 2003, the relative importance of the two pillars was reordered, with monetary analysis relegated to a secondary role. This shift reflected mounting empirical evidence of the instability of the money–inflation relationship at the time, as well as the practical observation that monetary policy decisions were already predominantly based on the economic analysis of risks to the price stability target (the non-monetary pillar; Hartmann and Smets, 2018). In the ECB's 2021 strategy review, the two pillars were finally merged into an integrated assessment comprising real and nominal economic developments (economic analysis) and monetary and financial indicators (monetary and financial analysis), with the latter focusing on the monetary transmission mechanism and financial stability risks rather than on monetary aggregates (ECB, 2021). The high-inflation episode from 2021 to 2023 did not lead to any re-evaluation of the role of money growth in the most recent ECB strategy assessment of 2025 (ECB, 2025a).

A comprehensive study of the recent inflation episode by contributors from across the Eurosystem concludes, based on an extensive literature review, that inflation was initially driven mainly by sectoral supply shocks, which later translated into broader price level increases at different speeds across the

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[2] For an overview of German monetary policy after the breakdown of Bretton Wood, we refer to Beyer et al. (2009), who argue that the Bundesbank's "money growth targets were regarded as constituting the basis for a rules-oriented approach to monetary policy."

economy (ECB, 2025b). Similarly, Arce et al. (2024) find a more limited role for demand factors such as labour market tightness and highlight the supply–demand imbalances caused by the pandemic. While the evidence is certainly persuasive, some commentators argue that earlier money growth may have supported household balance sheets, keeping demand more resilient and thereby amplifying the impact of transitory cost-push shocks on prices (Schnabel, 2023).

One of the core propositions of the quantity theory of money, reinvigorated by Friedman (1956), is the existence of a direct relationship between excess money growth and inflation (Jung, 2025). Since the 1970s, the phrase coined by Friedman (1963) that “inflation is always and everywhere a monetary phenomenon” has been challenged by both theoretical and empirical studies. In this classical view, sustained increases in the money supply translate directly into proportional increases in the price level, assuming stable money demand. Thus, in the long run and in the absence of velocity shocks, a one-to-one link between money growth and inflation is predicted and was examined extensively by empirical economic literature.

Early empirical studies supported the theory of a strong relationship between money growth and inflation (e.g. Cagan, 1956; Vogel, 1974; Lucas, 1980; Lothian, 1985; McCandless and Weber, 1995). From the 1990s onwards, however, money growth seems to have progressively lost predictive power, as the direct correlation with inflation weakened and ultimately disappeared (King and Watson, 1997; Stock and Watson, 2007; Assenmacher-Wesche and Gerlach, 2008; Woodford, 2008; Sargent and Surico, 2011; Teles et al., 2016; Gertler and Hofmann, 2018).

Despite this weakening through periods of inflation targeting and price stability, a relationship can still be observed over a long horizon (Benati, 2021). Ultimately, the long-run correlation depends on the inclusion of periods and countries with high inflation, whereas the relationship does not hold for low-inflation environments (De Grauwe and Polan, 2005; Benati, 2009; Fratianni et al., 2021; Jung, 2025). This empirical pattern motivates a strand of literature proposing more sophisticated models of multiple inflation regimes, investigating whether money growth can indicate switches between regimes of low and high inflation (Amisano and Fagan, 2013; Kaufmann 2015; Ringwald and Zörner, 2023).[3]

A few key takeaways from the empirical evidence are worth noting. There used to be a strong correlation between money growth and inflation, which, however, is conditional on the level of inflation: in countries or periods with low inflation, it becomes insignificant, whereas it remains strong in high-inflation environments (e.g. in Latin America, as studied by Sargent and Wallace, 1981). Generally, the link weakened or fully disappeared during the decades of the Great Moderation in advanced economies, as central banks started to target inflation directly (e.g. Bernanke et al., 1999). The empirical evidence pointing to a dependence on the level of inflation motivated a strand of literature that investigates the relationship between money growth and inflation across distinct inflation regimes. One hypothesis is that while there is no correlation between the two variables when the economy operates in a low-inflation regime, a significant relationship may exist during periods of high inflation. Naturally, even a significant correlation does not imply causality. Yet, as a leading indicator, money growth may provide useful information to improve inflation forecasts by signalling the risk of regime changes and may thus eventually serve as an input to a risk monitoring exercise for price stability (Amisano and Fagan, 2013; Borio et al., 2023a; Ringwald and Zörner, 2023).

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[3] Bordo et al. (2025) find a strong relationship between consumption and a Divisia M3 money measure for the United States, which is a constructed monetary aggregate that assigns different weights to its components. The authors argue that this relationship sheds light on the role of demand factors in the post-pandemic inflation episode.

3 Data and model

Our monthly dataset starts in January 1997 and ends in December 2024, resulting in 336 observations. As the monetary variable underlying our money growth indicator, we use M3, the main monetary aggregate employed by the ECB. We compute inflation as the annual change in the Harmonised Index of Consumer Prices (HICP). Finally, to proxy economic activity for the computation of money velocity, we rely on the industrial production index. Although this variable is more volatile than GDP, it represents the only readily available aggregate proxy for output at a monthly frequency. GDP is available only at a quarterly frequency and is subject to revisions, making it less suitable as an input for real-time policy analysis. Data sources and transformations are reported in table 2 in the annex.

3.1 Computing adjusted money growth

The quantity theory of money posits a direct and proportional long-run relationship between the money supply and the price level, assuming a constant velocity of money and exogenous output in the equation of exchange: $M_tV_t = P_tY_t$, where M_t denotes the monetary aggregate, V_t the velocity of money, P_t the price level and Y_t the output (Fisher, 1913). Taking logs and first differences of the equation (i.e. computing growth rates) and rearranging it to express inflation as the dependent variable shows that inflationary pressures cannot be inferred from raw money growth alone but require adjustment for the trend components of output and velocity growth.

Furthermore, if we were to assume that the trends in velocity and output were constant, we could simply adjust money growth using the average growth rates of velocity and output. However, there are several reasons against relying on raw, unadjusted money growth for the subsequent analysis. Both the trends in velocity and output growth may vary over time and thus bias the signal derived from money growth. Bordo and Jonung (2018), for instance, show that velocity (and its trend) is subject to a variety of economic, socio-economic and institutional factors and is therefore not necessarily constant. The same holds for trend output growth, which depends on factors such as labour force developments, productivity growth and other structural influences (e.g. the effects of the artificial intelligence revolution). In addition, crisis events can have long-lasting effects on potential output and thus on the trend (for evidence on euro area potential output in the post-crisis period, see Andersson et al., 2018).

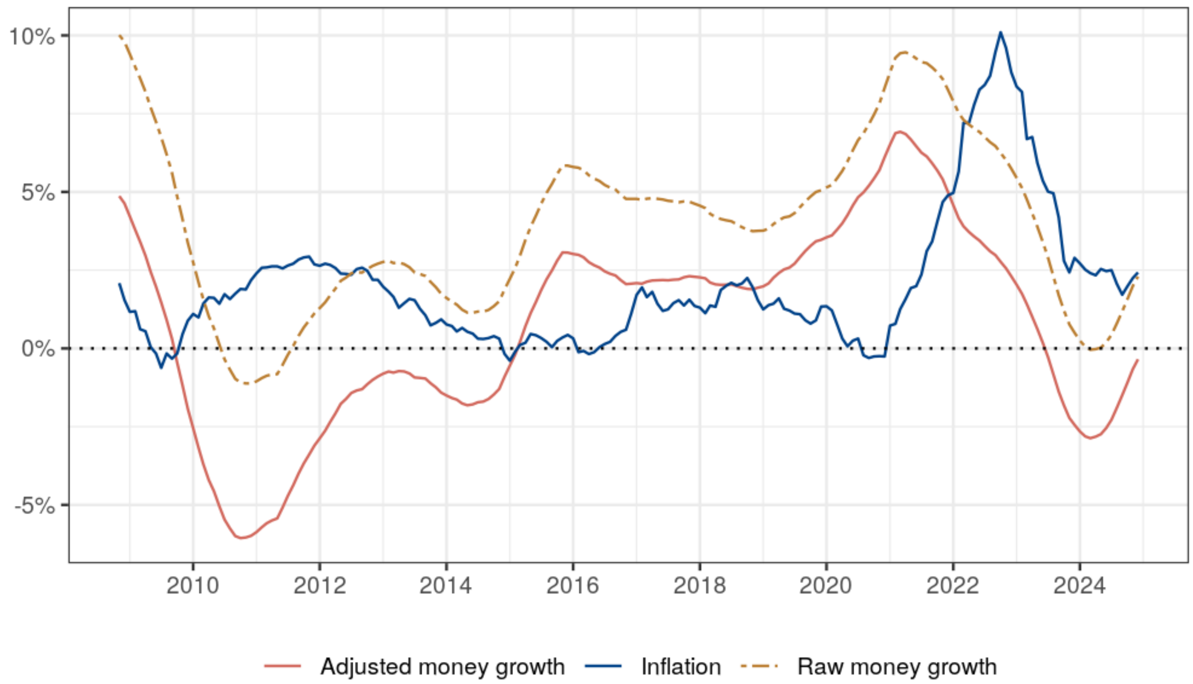
Hence, following Amisano and Fagan (2013), we adjust money growth, Δm, by time-varying trend velocity growth, $\Delta\tilde{v}$, and trend production growth, $\Delta\tilde{y}_t$:

$$\Delta m_t^* = \Delta m_t + \Delta\tilde{v}_t - \Delta\tilde{y}_t$$

First, we present our measure of the velocity of money, which is derived directly from the equation of exchange, calculating $V_t = \frac{P_tY_t}{M_t} = \frac{HICP_t * IP_t}{M3_t}$ on a monthly frequency, where HICP denotes the euro area Harmonised Index of Consumer Prices and IP refers to euro area industrial production. We then calculate the time-varying trends of velocity growth and production growth as sample means over a 10-year rolling window of lagged observations. This approach is costly in the sense that it discards the first $w = 120$ observations of our sample, but it allows the model to remain more tractable than, for example, when using more involved methods, which come with their own well-known limitations (Hamilton, 2018). After adjusting money growth for these trends in velocity growth and production growth, we take a moving average of the last 12 months. This helps smooth out temporary shocks that do not affect future inflation. The result, finally, is our adjusted money growth indicator, denoted as Δm_t^* in the subsequent section. Given the relatively short time span of our data, shifts in trend velocity and production growth may not be as impactful as over a longer time horizon.

Chart 1

Inflation, adjusted money growth and smoothed raw money growth



Note: Year-on-year raw M3 growth, adjusted M3 growth (10-year rolling window) and inflation, all in %. The two money growth measures are smoothed by taking a moving average over 12 periods.

Source: Authors' computations.

The effect of adjusting raw money growth by rolling-window trend output growth and trend velocity growth is illustrated in chart 1. "Raw" money growth refers to the moving average of unadjusted money growth that is not corrected for trends in output or velocity. Compared with this measure, the adjusted money growth indicator is lower throughout the sample period. This difference is mainly driven by trend velocity growth, which is negative for most of the sample and rises only briefly to values close to zero in 2019 and early 2020. Trend output growth also exerts a mostly negative effect, although its contribution is considerably smaller.

As a result, the overall trajectory of adjusted money growth resembles that of the raw series but is shifted downwards once trend velocity and output growth are taken into account. Importantly, this shift is not constant and therefore does not merely act as a scaling factor in the estimate. The gap between raw and adjusted money growth was relatively large (around five percentage points) in 2008 but declined thereafter, reaching its lowest level during the COVID-19 period. While raw money growth peaked during the global financial crisis, the adjustment places relatively greater emphasis on the COVID-19 pandemic. Without this correction, the money growth indicator may overstate the probability of an inflation regime change during the low-inflation period of the 2010s and understate risks to price stability in the post-pandemic period.

3.2 The logistic smooth transition autoregressive model

We now proceed with a more systematic approach to extract a potential signal from adjusted money growth to identify inflation regime switches. We conceptualise inflation as a two-regime process, where the switch between a low- and a high-inflation regime is modelled as gradual. This may reflect the assumption that economic agents adjust their decisions only gradually, or that two groups of agents coexist with differing assessments of the current state of the economy. In this sense, the framework is conceptually distinct from a Markov switching model, which governs abrupt, probabilistic state changes that depend only on the previous (latent) state. Instead, our approach allows for continuous and smooth transitions between regimes governed by the observable transition variable, adjusted money growth, and a parametric transition function. While our primary interest lies in extracting the signal rather than in exploring the underlying causal mechanisms, our model is also particularly suitable for modelling structural adjustments or asymmetric economic dynamics.

To capture potential differences in statistical properties between periods of low and high inflation, we continue with a two-state logistic smooth transition autoregressive (LSTAR) model proposed in Ringwald and Zörner (2023). The model allows a smooth switch between two inflation regimes $i = 1{,}2$, which we refer to as “low” and “high,” respectively, evolving as differing autoregressive processes of lag order $k \in \mathbb{N}$,

$$\pi_t = \phi'_1 z_t (1 - F_t) + \phi'_2 z_t F_t + \epsilon_t.$$

Here π_t is the HICP inflation at time $t = 1, \ldots, T$, z_t is a vector containing a constant and k lags of π, ϕ_i is a vector of coefficient parameters for the constant and each lag of inflation regime i. The Gaussian error term ϵ_t has mean zero and a time-varying log variance $e^{h_t/2}\omega_t$ and can thus be described by a stochastic volatility model (SV; Taylor, 1982). We also follow Kastner and Frühwirth-Schnatter (2014) and assume that h_t evolves as an AR(1) process $h_t = \iota + \rho(h_{t-1} - \iota) + \sigma\eta_t$. ω_t and η_t are i.i.d. standard normally distributed.

Finally, $F_t \in [0{,}1]$ is the logistic function determining the transition between the low-inflation regime ($i = 1$) and the high-inflation regime ($i = 2$), such that

$$F_t(\varDelta m_t^*, d, \gamma, c) = \left[1 + exp\left\{-\frac{\gamma}{\sigma_m}(\varDelta m_{t-d}^* - c)\right\}\right]^{-1}.$$

In our application, the money growth indicator is the transition variable $\varDelta m_{t-d}^* \in \mathbb{R}$, where $d \in \mathbb{N}$ is the delay parameter determining the lag of the transition variable. The threshold parameter $c \in \mathbb{R}$ governs how high the lagged money growth indicator must rise to trigger a transition from the low regime to the high regime. A switch happens if $\varDelta m_{t-d}^* > c$. Finally, the smoothing parameter $\gamma \in \mathbb{R}^+$, which is normalised by dividing by the standard deviation of the transition variable σ_m, controls the speed of transition. As $\gamma \to \infty$, the transition becomes effectively instantaneous, while a lower value of γ slows it down.[4]

We adopt a Bayesian approach to estimation and specify the priors following Ringwald and Zörner (2023), where a more detailed discussion of the underlying choices and techniques can also be found. As determining the joint distribution of c and γ is a non-trivial task, we resort to a Gibbs-style sampler with

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[4] Note that we use an autoregressive model and therefore we do not explicitly account for structural factors such as supply shocks. Extending the framework to include these variables is beyond the scope of this paper and left for future research. Accordingly, our objective is not to identify structural mechanisms, and thus the results should be interpreted as capturing reduced-form dynamics, with money growth serving as an empirical indicator rather than a structural proxy.

a reversible-jump Markov chain Monte Carlo (RJMCMC) and a multiple-try Metropolis (MTM) step. One difference in our set-up is that the delay parameter $d \in \{0,\dots,48\}$ is initialised at $d_{init} = d_{max} = 48$ to account for the use of monthly data. The AR lag order $k \in \{0,\dots,10\}$ is initially set to $k_{init} = k_{max} = 10$. We run 60,000 iterations, the first 30,000 of which are discarded as burn-in. The remaining 30,000 iterations are saved, with results (median along some percentiles) being presented in the following subsection.

4 Results

Based on the estimate, table 1 reports the median as well as the 95% credible interval (the 2.5th and 97.5th percentiles) of the posterior distribution of the estimated parameters conditional on $\mathrm{k}^* = 1$ and $d^* = 10$, the most drawn lag order and delay parameter. Given the preferred lag order of $k^* = 1$, found in 100% of saved iterations, we conclude that inflation in both regimes is best described as an autoregressive process of order 1, that is a simple AR(1) process. Here, $\phi(i,0)$ represents the constant for the low- and high-inflation regimes $i = 1{,}2$ and consequently $\phi(i,1)$ the respective regime's AR(1) parameter. Note that, unlike Amisano and Fagan (2013), who model abrupt switches between regimes, our approach captures gradual adjustments and provides a signal based on an observed variable, avoiding reliance on unobserved regime classifications.

While the constant itself does not reveal the unconditional mean, the latter can be inferred as $\frac{\phi(i,0)}{1-\phi(i,1)}$ for $i = 1{,}2$. For the low-inflation regime, the mean is therefore 1.2%. However, the mean for the high-inflation regime appears unreasonably high. It should be noted that when inspecting the transition function later, only a limited amount of time is assigned to the high-inflation regime, so the estimate of the coefficients for this regime relies on few observations, as also reflected by the large credible interval. If we use the 2.5th percentile value, this will imply an unconditional mean of around 12.7%, which is quite close to the inflation peak of 11.6% in October 2022.

In both regimes, the autoregressive coefficients are rather high and thus indicate persistent dynamics. In the high-inflation regime (i = 2), the coefficient is slightly higher, implying even more persistence in this regime. In other words, once inflation enters this regime, it tends to remain elevated for an extended period before gradually returning to lower levels. This aligns well with the stylised facts of inflation, as noted and documented by Borio et al. (2023b). This persistence suggests that monetary policymakers may need to respond more forcefully when the economy is in a high-inflation regime to prevent inflation expectations from becoming de-anchored and to guide inflation back towards its target, given the high mean in this regime.[5]

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[5] As a technical sidenote, we cannot rule out that the high-inflation regime features non-stationary dynamics, as the credible interval includes one. This is consistent with the findings of Ringwald and Zörner (2023), who also observed this for the USA. This suggests that a high-inflation regime may exhibit non-mean-reverting dynamics, potentially associated with de-anchoring of inflation expectations. However, a deeper analysis of this issue goes beyond the scope of this paper.

Table 1

Posterior results of the LSTAR model

Parameter	Interpretation	Median	2.5th percentile	97.5th percentile	Mode
$\boldsymbol{\phi}(\mathbf{1},\mathbf{0})$	Constant regime 1	0.06	-0.01	0.12	-
$\boldsymbol{\phi}(\mathbf{1},\mathbf{1})$	AR parameter regime 1	0.95	0.91	0.99	-
$\boldsymbol{\phi}(\mathbf{2},\mathbf{0})$	Constant regime 2	0.66	0.38	1.27	-
$\boldsymbol{\phi}(\mathbf{2},\mathbf{1})$	AR parameter regime 2	0.97	0.88	1.00	-
c	Threshold parameter	4.81	3.98	5.56	-
$\boldsymbol{\gamma}$	Smoothing parameter	8.77	4.68	15.92	-
k	Lag order	-	-	-	1 (100%)
d	Delay parameter	-	-	-	10 (36.87%)

Note: Median, 2.5th percentile and 97.5th percentile of saved parameter draws (after discarding 30,000 burn-in iterations), conditional on the most selected lag order $k^* = 1$ and delay parameter $d^* = 10$ (respective share of total saved draws in parentheses). $\phi(i,j)$ denotes the autoregressive coefficient for inflation regime $i \in \{1,2\}$ and lag j.

Source: Authors' computations.

We now turn to the estimates for the threshold parameter c, which determines how high adjusted money growth (after the delay d^*) must be to trigger a change in the inflation regime. The median estimate of c is 4.81, and approximately 94% of the posterior mass lies between 4 and 5.5, indicating that the parameter is estimated with considerable precision. According to our model, if adjusted money growth exceeds roughly 5%, a transition to the high-inflation regime is triggered after about ten months. Similarly, Jung (2025) employs a threshold of 5% excess money growth in analysing the money–inflation nexus, although based on a much larger sample and without estimating the threshold. His approach builds on recent studies that apply an inflation threshold, above which the relationship between money growth and inflation strengthens (Borio et al., 2023a; Borio et al., 2023b). In contrast, we provide an empirically estimated threshold for adjusted money growth that spans the two regimes in our framework. Compared to quarterly results of the USA and UK, the thresholds are somewhat higher, while lower values have been found for Canada, which may also reflect the higher data frequency in our study.

The smoothing parameter γ determines how gradually the model moves from one inflation regime to another: the higher γ is, the faster the transition happens. Our results also indicate that the regime switches occur relatively quickly, though not instantaneously, which is in line with findings for the USA, UK and Canada.[6]

Finally, chart 2 shows the results for the delay parameter d. The most common value, $d^* = 10$, appears in about 37% of the retained posterior draws, considerably more often than would be expected under our prior assumption. Most of the remaining estimates cluster around this value, indicating that the model assigns substantial probability to a delay of roughly ten months in capturing the link between money growth and inflation. At the same time, some draws suggest a substantially longer delay, close to 40

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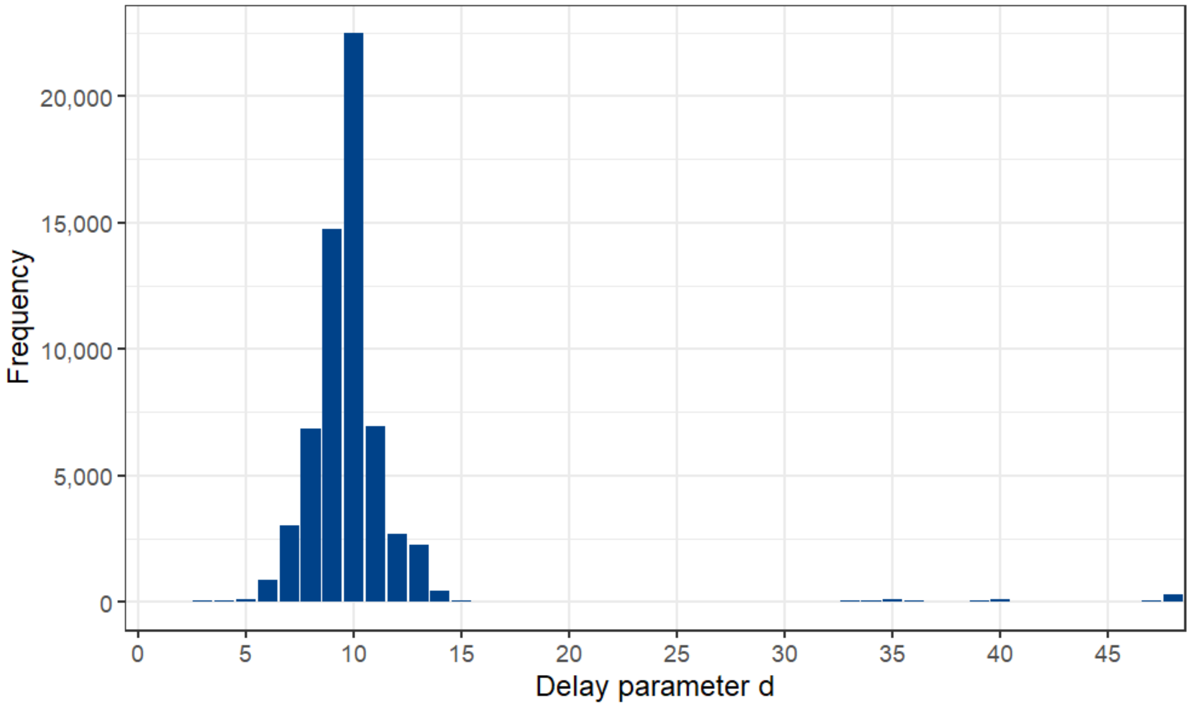
[6] Whenever we compare our findings with those for the USA, UK or Canada, we refer to Ringwald and Zörner (2023) as the benchmark.

months. Given the limited sample available for the euro area, future research could revisit this analysis to examine whether the distribution of the delay parameter changes with additional data or whether this pattern reflects a structural feature of the euro area economy. As noted earlier, the values reported in table 1 are based on the model outcomes using $k = 1$ and $d = 10$.

Chart 2

Distribution of delay parameter *d*



Note: Draws for delay parameter d over all 60,000 iterations. Distribution does not change noticeably after discarding the burn-in iterations.

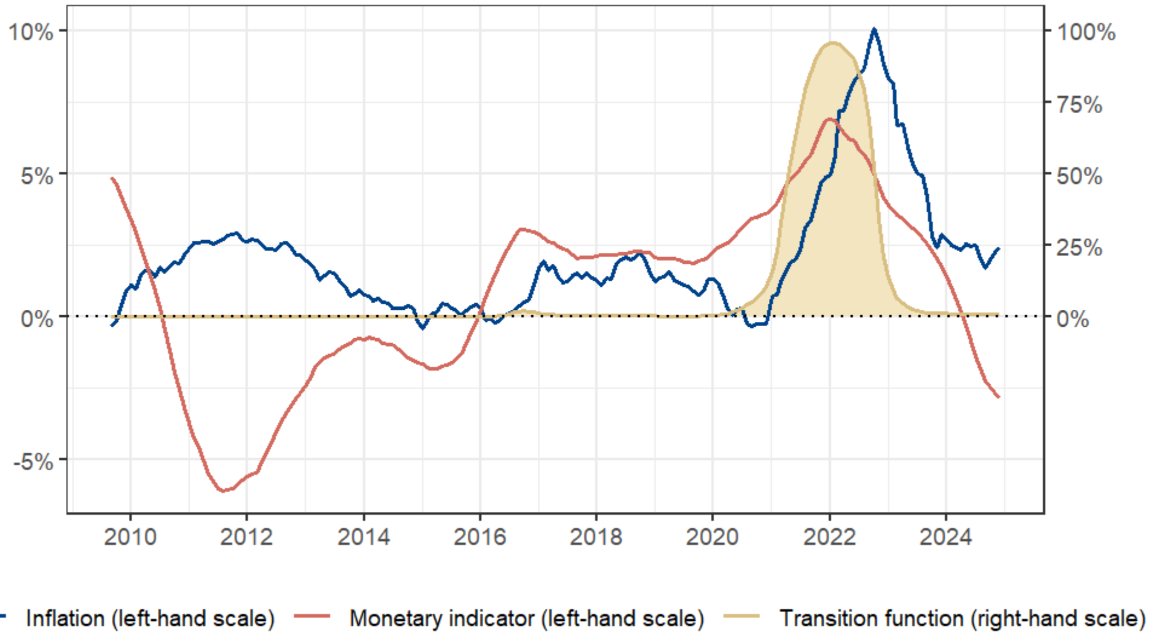
Source: Authors' computations.

We continue with a graphical presentation of the transition function, the monetary indicator driving the regime switch and the inflation rate of the euro area.

The beige line of chart 3 shows the median of the transition function $F_t \in [0,1]$ which indicates the weighting between the low-inflation regime and the high-inflation regime (right-hand scale, ranging from zero to one). In principle, the advantage of the smooth transition model is that it provides an explicit transition function, allowing policymakers to determine when entering the high regime. If we assume that $F_t = 0.5$ is a suitable benchmark for policymakers to assign the regimes, the model assigns a high probability of being in the high-inflation regime from May 2021 to October 2022, with the high-regime weight peaking in January 2022. This corresponds well to the observed rise in inflation during the post-pandemic period, with October 2022 marking the month of peak inflation in the euro area at 11.6% (inflation is shown in blue on the left-hand scale).

Chart 3

Transition function



Note: Inflation in blue and the monetary indicator delayed by $d^* = 10$ periods in red on the left-hand scale (both in %). In beige, on the right-hand scale, the unconditional posterior means of the transition function $F_t \in [0,1]$ showing regime weights between the low- and the high-inflation regime for each period.

Source: Authors' computations.

However, the model already assigns the 2023 period of high but declining inflation to the low-inflation regime. Comparing the money growth indicator in chart 3 with that in chart 1 (both in red) clearly shows a rightward shift by ten months, reflecting our inferred delay parameter d^*. Without this preferred delay, adjusted money growth might have signalled a switch to the high-inflation regime ten months earlier, precisely when the euro area experienced five months of deflation at the height of the COVID-19 pandemic. This underscores the importance of identifying an appropriate delay parameter. The estimated delay for the euro area is shorter than for the USA but longer than for the UK and Canada; however, comparability is limited, as these estimates are based on quarterly data.

4.1 Robustness

In this section, we briefly discuss the robustness of our results to an alternative monetary indicator, different rolling-window and moving-average lengths and alternative filtering methods. Consistent with evidence from other advanced economies (Ringwald and Zörner, 2023), the choice of money growth adjustment critically affects the results, which is confirmed here for the euro area. Our preferred adjustment method, which relies on rolling-window correlations, has two advantages over more sophisticated filtering approaches. First, it mitigates the endpoint bias inherent in filters such as the Hodrick-Prescott (HP) filter. Second, it is straightforward to implement and can be applied in real time, provided that money growth, inflation and industrial production data are available.

Chart A1 presents results using Divisia money growth as the monetary indicator. This specification produces a smoother and somewhat more gradual transition function, which begins to rise earlier and remains elevated for a slightly longer period around the inflation surge. This suggests a more continuous relationship between monetary conditions and inflation. In contrast, when adjusted M3 is used, the transition function is more concentrated and peaks sharply around 2021/2022, indicating that the model identifies a shorter and more abrupt regime associated with the inflation spike. These findings suggest that policymakers may benefit from monitoring both Divisia money and adjusted M3, as the two indicators provide complementary signals: Divisia offers a smoother and earlier indication of evolving monetary conditions, while adjusted M3 highlights sharper shifts during periods of pronounced inflationary pressure. Chart A5 shows that the two-sided HP filter yields similar results, while other filtering methods fail to identify the high-inflation period, resembling the results obtained when using the broad M3 aggregate, as discussed in the following paragraph.

Charts A2 and A3 compare different lengths of the rolling window and the moving average, respectively. While the results are relatively robust to the choice of moving average length, they are more sensitive to the length of the rolling window. As the rolling window becomes shorter, the transition function becomes increasingly volatile. Shorter windows (e.g. 60 to 84 months) generate frequent regime switches and prolonged high-regime periods, suggesting that the estimates become more sensitive to short-term fluctuations. In contrast, our preferred specification with a 120-month rolling window produces a smoother and more stable transition pattern, identifying the high-inflation regime mainly around the 2021/2022 period while avoiding spurious regime changes earlier in the sample.

Finally, Chart A4 illustrates the sensitivity of the results to alternative filtering methods. Notably, only our preferred specification identifies the high-inflation episode that followed the COVID-19 pandemic. HP filtering exhibits the well-known endpoint bias, leading to counter-intuitive results. The Hamilton filter assigns the period from 2014 to 2017 to the high-inflation regime while failing to detect the inflation surge after the pandemic. Similarly, using raw money growth does not capture the post-COVID-19 inflation surge and instead identifies the period from late 2024 onwards as the high-inflation regime. Given this lack of robustness across alternative filtering approaches, future research should examine these differences more closely. In particular, analyses aimed at informing real-time policymaking should carefully account for the sensitivity of results to the chosen adjustment method.

The high-inflation regime identified by the model is largely concentrated between 2021 and 2023, reflecting the fact that the recent inflation surge represents the most pronounced inflation episode in the euro area during our sample. This contrasts with Ringwald and Zörner (2023), who analyse a sample of countries containing several such episodes, while in euro area aggregate data, comparable inflation regimes are rare.

4.2 Discussion

While our economic and financial system is arguably more complex than in Goethe’s time, the relationship between money growth and inflation remains a matter of ongoing debate. The post-pandemic surge in inflation in the euro area and other economies starting in 2021 has not only prompted a return to conventional monetary policy but also reinvigorated the long-standing academic debate on money growth and price dynamics.

Our finding that a monetary indicator of adjusted money growth can successfully assign a period of rising inflation to a high-inflation regime naturally raises the question of the implications for the money growth–inflation debate. Importantly, our results do not imply a causal link between the growth of monetary aggregates and inflation. The correlation may be spurious and economically irrelevant (Papadia and Cadamuro, 2021). Crises such as the COVID-19 pandemic may also act as confounders:

extraordinary events in which central banks provide liquidity while geopolitical pressures increase the risk of supply shocks and demand remains highly unpredictable. Given our sample, this may also be the case here.

In any case, our findings support the idea of different inflation regimes informed by monetary growth: low-inflation regimes, in which price stability and monetary aggregates are uncorrelated, and high-inflation regimes, in which the relationship becomes significant. The transition between these regimes can then be predicted by an appropriate measure of money growth. By considering the development of money growth, policymakers may, on the one hand, benefit from improved forecasts during periods of high inflation (Borio et al., 2023a), and, on the other hand, receive early signals of the risk of transitioning into a high-inflation regime. The latter, however, relies on a robust indicator variable that can be transparently calculated in real time, together with a good understanding of the delay between the signal and the underlying event.

Ultimately, our results confirm the findings of the benchmark study, which identifies large cross-country differences in the appropriate delay of the monetary indicator. A delay of ten months reflects a comparatively short interval between the growth of the broad money aggregate during the COVID-19 pandemic and the quickly rising price level in post-pandemic times, amid supply chain interruptions, the Russian invasion of Ukraine and persistently strong aggregate demand. In contrast, the authors find a significantly longer delay of two and a half years for the USA, but a shorter delay of only zero or one quarter, respectively, for the UK and Canada. Another issue highlighted is the dependence on the chosen money growth adjustment. Results are shown to lack full robustness to changes in the method used to derive trends in velocity growth and output growth for the money growth adjustment. Our choice of a rolling-window filter replicates Amisano and Fagan (2013) and has the benefit of being highly tractable and useful in real-time applications.

Finally, our analysis may also contribute to the ECB's approach of "modern monetary analysis." As Lane (2024) argues, this framework helps policymakers take the nexus of money, credit and the economy into account in a holistic manner. In particular, he emphasises that monetary analysis at the ECB has evolved from a narrow focus on the quantity of money to a broader perspective that considers how monetary policy transmits to the financing conditions faced by households and firms in the real economy. Especially our more robust results, such as the estimated lag order and range of the delay of the signal, may help to enrich these kinds of assessments. As more data become available over time, future research could revisit this analysis to examine whether our results are primarily driven by a single episode or instead represent a structural feature of the euro area economy. Moreover, the flexibility of our model within a Bayesian framework allows for the incorporation of additional data and prior information, thereby facilitating continuous updating and reassessment as new evidence emerges.

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6 Annex

6.1 Data sources and variables

Table A1

Data sources and variables

Variable	Mnemonic	Coverage/ composition	Adjustment	Source or ECB data portal code	Notes
Monetary aggregate	M3	Euro area	Working-day and seasonally adjusted	BSI.M.U2.Y.V.M30.X.1.U2.2300.Z01.E	
Divisia monetary aggregate	M3d	Euro area	Break-adjusted euro area (changing composition) “notional outstanding stock”	Darvas (2025)	Based on Darvas (2015)
HICP price index	Inflation, π	Euro area	Working-day and seasonally adjusted	ICP.M.U2.Y.000000.3.INX	Used to compute the inflation rate as annual change in consumer prices
Industrial production	IP	EA20	Working-day and seasonally adjusted	STS.M.I9.Y.PROD.NS0020.4.000	Serves as the output variable in the main analysis
Real GDP (for robustness check only)	GDP	Euro area (quarterly data)	Seasonally adjusted	Eurostat	Used in robustness analysis; results are qualitatively similar and available upon request

6.2 Robustness

6.2.1 Results with Divisia money growth as a transition variable

Table A2

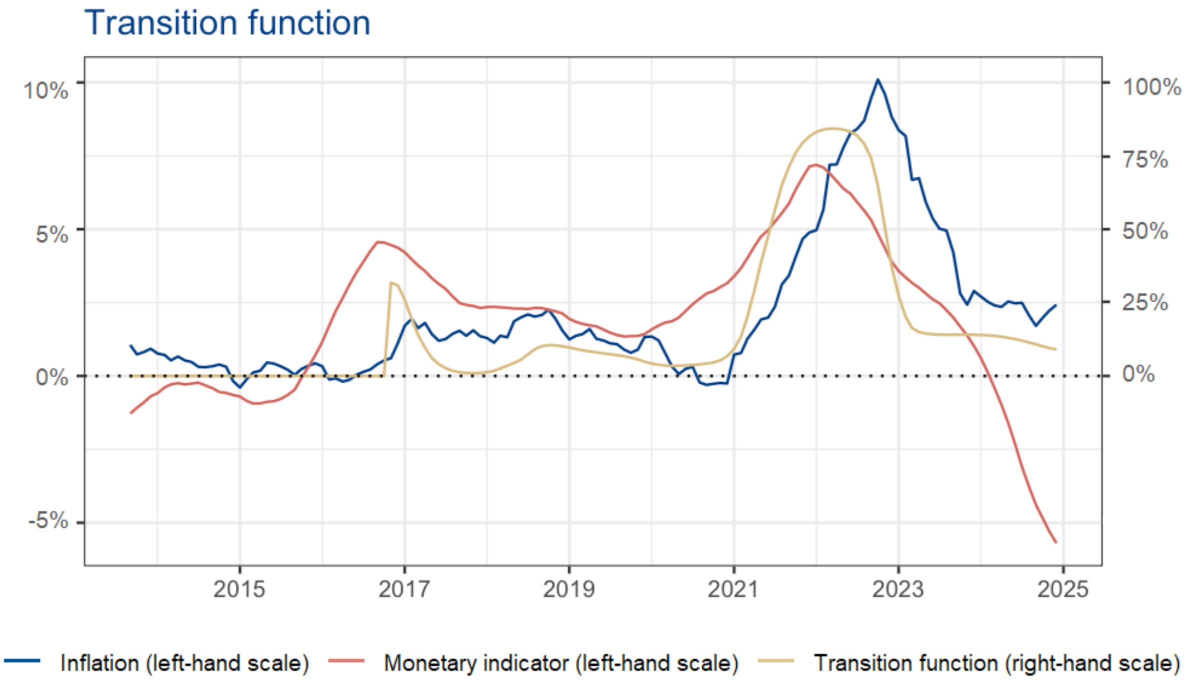
Posterior results with the Divisia monetary aggregate

Parameter	Interpretation	Median	2.5th percentile	97.5th percentile	Mode
$\boldsymbol{\phi(1,0)}$	Constant regime 1	0.03	-0.03	0.09	-
$\boldsymbol{\phi(1,1)}$	AR parameter regime 1	0.92	0.89	0.96	-
$\boldsymbol{\phi(2,0)}$	Constant regime 2	0.59	0.35	1.10	-
$\boldsymbol{\phi(2,1)}$	AR parameter regime 2	0.98	0.91	1.00	-
c	Threshold parameter	4.52	3.88	5.37	-
$\boldsymbol{\gamma}$	Smoothing parameter	8.36	4.44	15.28	-
k	Lag order	-	-	-	1 (100%)
d	Delay parameter	-	-	-	10 (26.29%)

Source: Authors' computations.

Chart A1

Transition function with Divisia money aggregate growth



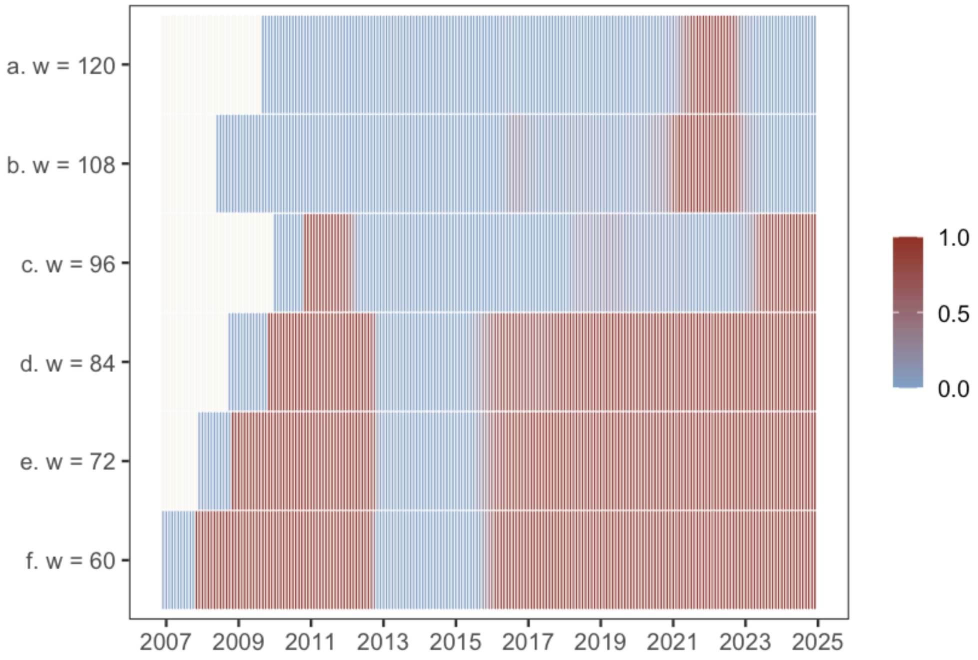
Note: Inflation in blue and the monetary indicator delayed by $d^* = 10$ periods in red on the left-hand scale (both in %). In beige, on the right-hand scale, the unconditional posterior means of the transition function $F_t \in [0,1]$ showing regime weights between the low- and the high-inflation regime for each period.

Source: Authors' computations.

6.2.2 Results with different lengths of the rolling window and the moving average

Chart A2

Comparison of transition function values with different rolling correlation windows

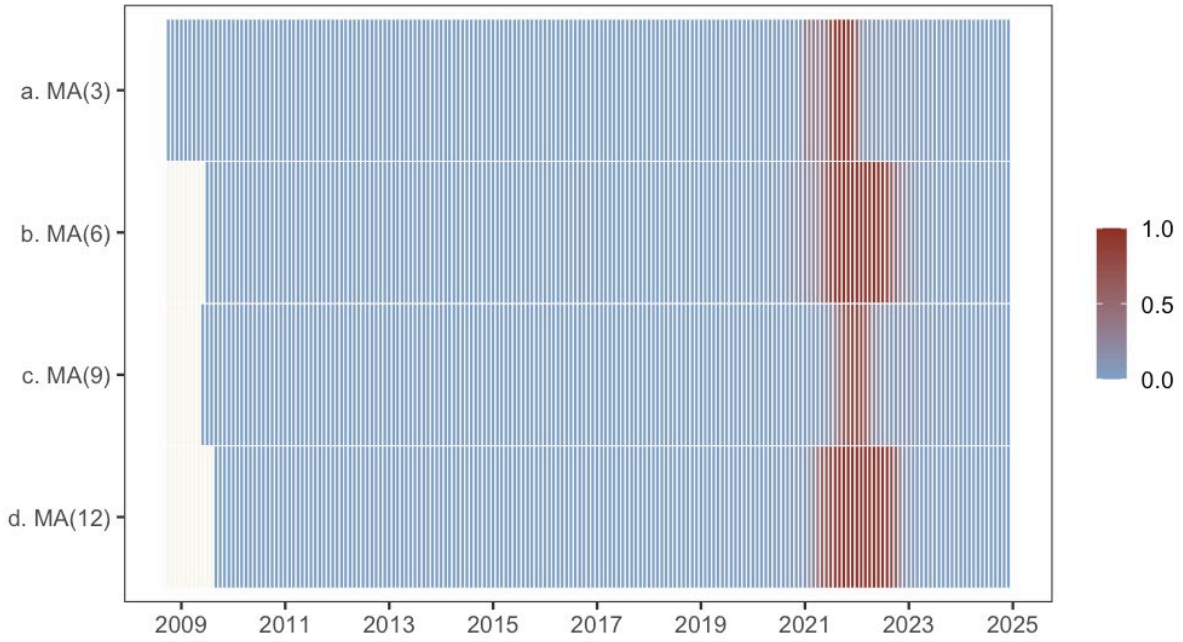


Note: This chart shows the heatmap of transition function values based on different lengths of the rolling window. Each cell corresponds to one month and the colour transitions from F_t=0 (blue) to $F_T = 1$ (red). F_t is computed from median values, conditional on lag length $k^* = 1$ and delay $d^* = 10$ for each model.

Source: Authors' computations.

Chart A3

Comparison of the transition function with different moving average lengths



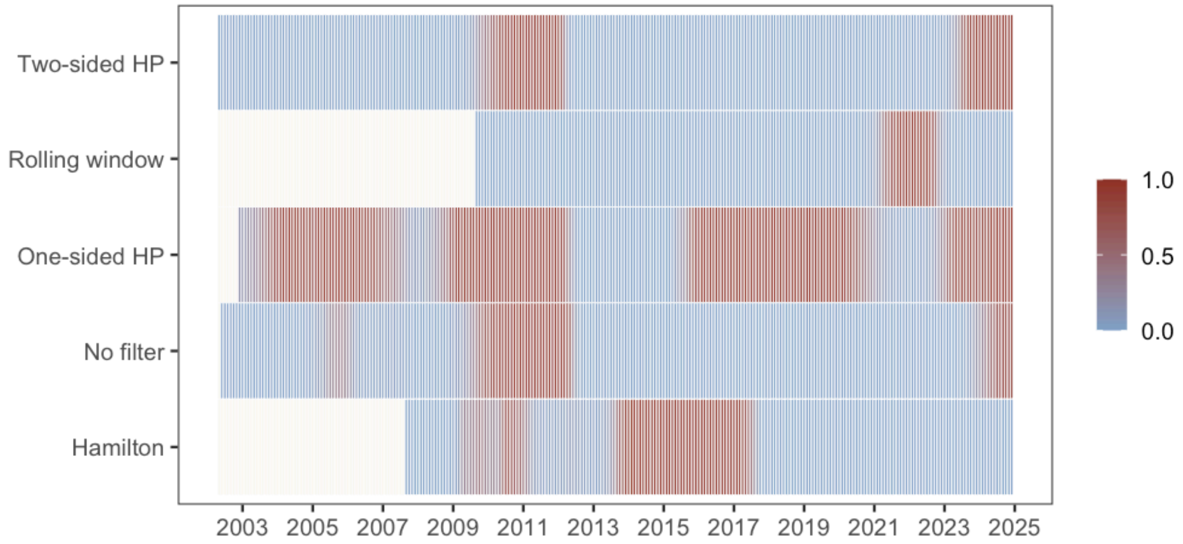
Note: This chart shows the heatmap of transition function values based on different lengths of the moving average to smooth adjusted money growth. Each cell corresponds to one month and the colour transitions from F_t=0 (blue) to $F_T = 1$ (red). F_t is computed from median values, conditional on lag length $k^* = 1$ and delay $d^* = 10$ for each model.

Source: Authors' computations.

6.2.3 Results with different filtering methods

Chart A4

Comparison of transition function values for different filtering methods

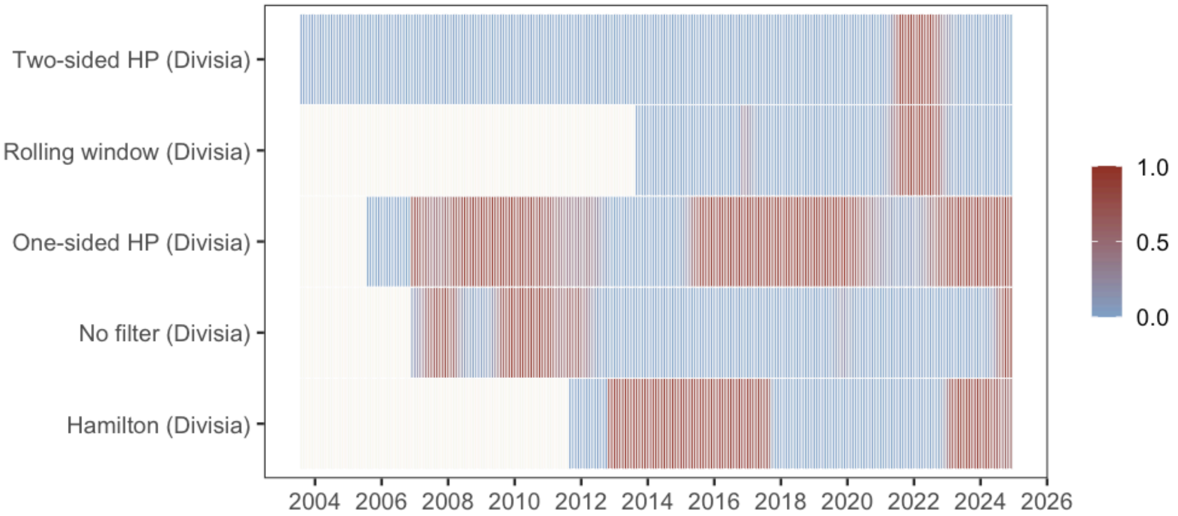


Note: This chart shows the heatmap of transition function values based on the two-sided HP filter (first row), the main specification of the paper (second row), the one-sided HP filter (third row), the results with raw money growth (fourth row) and the Hamilton filter (last row). Each cell corresponds to one month and the colour transitions from F_t=0 (blue) to $F_T = 1$ (red). F_t is computed from median values, conditional on lag length $k^* = 1$ and delay $d^* = 10$ for each model.

Source: Authors' computations.

Chart A5

Comparison of transition function values for different filtering methods with Divisia money growth



Note: This chart shows the heatmap of transition function values based on the two-sided HP filter (first row), the main specification of the paper (second row), the one-sided HP filter (third row), the results with raw money growth (fourth row) and the Hamilton filter (last row). Each cell corresponds to one month and the colour transitions from F_t=0 (blue) to $F_T = 1$ (red). F_t is computed from median values, conditional on lag length $k^* = 1$ and delay $d^* = 10$ for each model.

Source: Authors' computations.

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